Introduction to Hypersonic Aerothermodynamics

ASEN 5519-001, Fall 2021

Last updated: August 24, 2021

Instructor: Dr. Ross Chaudhry, ross.chaudhry@colorado.edu

Office hours: Weekly (time TBA) or by appointment, in person or over Zoom

Schedule: 2:50-4:05 PM, Tuesday and Thursday

In-person location: AERO N250

Remote location: Recurring Zoom meetings, `https://cuboulder.zoom.us/`

Website: `https://canvas.colorado.edu/courses/`

Grading

8 problem sets, 5% each	40%
1 midterm exam, October 28	25%
1 final exam, date TBD	35%
Total	100%

The assignments will be approximately evenly spaced throughout the semester. The late penalty for assignments is 10% per day, for up to 5 days. Beyond 5 days late, the assignment is worth 0%. Email me for accommodations due to illness or other extenuating circumstances.

Reference texts

There is no required textbook, but interested students may refer to the following books for further discussion and resources. Reading may be assigned from these books, but they will either be available online through the CU Library or the relevant sections will be provided.

- Bertin, "Hypersonic Aerothermodynamics", AIAA, 1994. Full text is available online through the library at `http://tinyurl.com/y292lqnt`.
- Anderson, "Hypersonic and High-Temperature Gas Dynamics", AIAA, 2006. Full text is available online through the library at `https://tinyurl.com/yyyxpjvr`.
- Hankey, "Re-entry Aerodynamics", AIAA, 1988. Full text is available online through the library at `http://tinyurl.com/yymhlaw9`.
- Heiser and Pratt, "Hypersonic Airbreathing Propulsion", AIAA, 1994. Full text is available online through the library at `https://tinyurl.com/yybuuvwh`.

Course Modalities

This course is offered in several modalities:

- **Hybrid: ASEN 5519-001** – students enrolled in this course code should attend class synchronously, either in person or remotely via zoom meeting. The zoom link is the same for each class: `https://cuboulder.zoom.us/` .
- **Online: ASEN 5519-001B** – students attend class asynchronously by watching recordings of the ASEN 5519-001 lectures on their own time.

You should be registered in the class code corresponding to the mode you expect to dominantly use. However, all students are permitted to attend the zoom meetings synchronously, and recordings will be made available for all students. Lecture notes or slides will also be posted, when applicable.

Course Material and Outline

1. Introduction [1 lecture]
    - Course outline
    - Broad overview of hypersonics
2. Hypersonic flight mechanics [3 lectures]
    - Trajectory equations
    - Ballistic entry (missile)
    - Equilibrium glide (Space Shuttle)
    - Air-breathing, powered flight
3. Aerothermodynamics phenomena [7 lectures]
    - Review of compressible gas dynamics
    - High-temperature gas effects
    - Nonequilibrium thermochemical kinetics
    - Guest lecture: Prof. Robyn MacDonald
    - Fluid conservation equations
    - Molecular transport processes
    - Review of aerodynamics
4. Surface pressure [3 lectures]
    - Stagnation point
    - Newtonian models
    - Sharp cones
5. Boundary layers [3 lectures]
    - Self-similar equations
    - Solution for a flat plate
    - Stagnation-point heating (Fay-Riddell)
6. Heat transfer and skin friction [2 lectures]
    - Surface temperature
    - Laminar and turbulent boundary layers
7. Hypersonic propulsion [2 lectures]
    - Rockets and ramjets
    - Scramjets
8. Thermal Protection Systems [3 lectures]
    - Design drivers
    - Passive (Space Shuttle, X43)
    - Ablative (Stardust)
    - Guest lecture: Prof. Tim Minton
9. Cutting-edge capabilities (subject to change) [2 lectures]
    - Computational tools
    - Experimental facilities
10. Conclusions and exam preparation [1 lecture]

Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on classroom behavior and the Student Conduct & Conflict Resolution policies.

Requirements for COVID-19

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

As of Aug. 13, 2021, CU Boulder has returned to requiring masks in classrooms and laboratories regardless of vaccination status. This requirement is a temporary precaution during the delta surge to supplement CU Boulder's COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home. In this class, if you are sick or quarantined, email me and I can provide appropriate accommodations. You do not need to state the nature of your illness, nor is a doctor's note or other verification required.

Accommodation for Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the Honor Code website.

Sexual Misconduct, Discrimination, Harassment, and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or email cureport@colorado.edu. Information about OIEC, university policies, reporting options, and the campus resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options.

Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please let me know of the conflict by email and I will work to accommodate your specific situation.

See the campus policy regarding religious observances for full details.